Volume 1 FEBRUARY 13, 1926 Number 7

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM FOR THE

MONTREAL MEETING

FEBRUARY 26-27, 1926

JOINT MEETING WITH THE OPTICAL SOCIETY OF AMERICA

AT McGILL UNIVERSITY

PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY
SIX ISSUES EACH YEAR

The American Physical Society

OFFICERS OF THE SOCIETY FOR 1926

President	DAYTON C. MILLER	Case School of Applied Science
Vice-President	K. T. COMPTON	Princeton University
Secretary	H. W. WEBB	Columbia University
Treasurer	G. B. PEGRAM	Columbia University
Editor	JOHN T. TATE	University of Minnesota
Local Secretary for the Pacific Coast	D. L. WEBSTER	Stanford University

COUNCIL

The Council of the Society consists of the president, vice-president, secretary, treasurer and managing editor as given above, and all living past presidents and eight elected members as follows:

Past Presidents: A. A. Michelson, Carl Barus, E. L. Nichols, Henry Crew, W. F. Magie, Ernest Merritt, R. A. Millikan, J. S. Ames, Theodore Lyman, C. E. Mendenhall.

Elected Members: F. C. Brown, A. L. Hughes, A. S. Eve, A. W. Hull, F. C. Blake, W. F. G. Swann, A. H. Compton and E. P. Lewis.

BULLETIN

of the

AMERICAN PHYSICAL SOCIETY

Published six times per year

Subscription price: $1.00 per year.

The Bulletin of the American Physical Society is published six times a year during the months of February (2 issues), April, June, November, and December at 450 Ahnaip Street, Menasha, Wisconsin.

Address correspondence to Secretary H. W. Webb, Columbia University, New York, N. Y.

Entered at the post office at Menasha, Wisconsin, as second class matter.

FEBRUARY 13, 1926 Vol. I, No. 7

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

MONTREAL MEETING, FEBRUARY 26-27, 1926

JOINT MEETING WITH THE OPTICAL SOCIETY OF AMERICA

The 137th regular meeting of the American Physical Society will be held in Montreal at McGill University on February 26-27, 1926, as a joint meeting with the Optical Society of America. The sessions will be held in the Macdonald Physics Building. On Friday morning beginning at 9:30 there will be a session of the Optical Society of America (room to be announced). Sessions of the American Physical Society will be held on Friday morning and afternoon and on Saturday morning, all in the lecture-theatre of the Physics Building.

Dinner. The Chancellor, the Principal, and the Board of Governors of McGill University invite members of the American Physical Society and of the Optical Society of America to dinner at 7 o'clock on the night of Friday the 26th of February. Those who are able to accept are requested to *answer this invitation at least one week in advance, to the Director, Macdonald Physics Building, McGill University, Montreal.*

Hotels. As there are many winter visitors in Montreal, it is advisable to secure rooms well in advance. Following is a list of hotels and prices. Mount Royal Hotel (Headquarters), single rooms $3.50, double rooms $6.00, all with bath; Ritz-Carlton Hotel, single rooms $4.00, double rooms $7.00; Windsor Hotel, single rooms $3.00, double rooms $5.00 or $6.00; Queens Hotel, single rooms $3.00, double rooms $5.00.

Members of the Societies bringing with them apparatus, etc., for use at the meeting are advised that the Collector of Customs at Montreal will accept entry of these articles into Canada, without duty, conditional upon their being exported under Customs supervision at the close of the meeting.

On Thursday evening at 8:15 o'clock DOCTOR W. J. HUMPHREYS will deliver an address at the Royal Victoria College on "Clouds and Cloud Phenomena." Members of the Societies are invited to attend.

On Friday afternoon at 3 o'clock PROFESSOR FRANK ALLEN of the University of Manitoba will deliver a lecture, by invitation of the Optical Society, on "The Second Half of Vision."

Titles and abstracts of all papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts of the Physical Society papers will be published in the Physical Review, and the Optical Society papers in the Journal of the Optical Society of America. Authors should send corrections to the editors of the respective journals.

HAROLD W. WEBB, *Secretary*,
Columbia University, New York City.

February 13, 1926.

CALENDAR

Thursday evening at 8:15 o'clock	Lecture by DOCTOR W. J. HUMPHREYS
Friday morning at 9:30 o'clock	Session of the Optical Society of America
Friday evening at 7 o'clock	Dinner
Sessions of the American Physical Society:	
Friday morning at 10 o'clock	Papers 1–13
Friday afternoon at 2 o'clock	Papers 14–24
	Lecture by PROFESSOR FRANK ALLEN.
Saturday morning at 10 o'clock	Papers 25–37

The supplementary papers Nos. 38–39 may be called for at the end of any session of the Physical Society.

Other meetings of the Physical Society during the current season are as follows:
138. March 6, 1926. Pacific Coast Section at Stanford.
139. April 23–24, 1926. Washington.
140. June 18, 1926. Pacific Coast Section at Mills College, Oakland, California.

PROGRAM

FRIDAY MORNING AT 9:30 O'CLOCK

Macdonald Physics Building

Session of

THE OPTICAL SOCIETY OF AMERICA

OFFICERS

President, W. E. FORSYTHE, Nela Park, Cleveland
Vice-President, I. G. PRIEST, Bureau of Standards
Secretary, pro tem., F. K. RICHTMYER, Cornell University
Treasurer, ADOLPH LOMB, Bausch & Lomb Optical Co.
Council: Consists of the above officers, H. E. Ives, Paul D. Foote, K. T. Compton, C. E. K. Mees, P. G. Nutting, and C. W. Keuffel.

The annual meeting of the Optical Society is held in October of each year.

ABSTRACTS OF PAPERS*

1. Ludwik Silberstein	Research Laboratory, Eastman Kodak Company
2. Dr. Clayton H. Sharp	Electrical Testing Laboratories
3. L. A. Jones and V. C. Hall	Research Laboratory, Eastman Kodak Company
4. Harley E. Howe	Cornell University
5. K. S. Gibson	Bureau of Standards
6. Irwin G. Priest	Bureau of Standards and Munsell Research Laboratory
7. Irwin G. Priest and F. C. Brickwedde	Bureau of Standards and Munsell Research Laboratory
8. W. F. Meggers and C. C. Kiess	Bureau of Standards
9. Irwin G. Priest	Bureau of Standards and Munsell Research Laboratory

---

1. Ludwik Silberstein — **Research Laboratory, Eastman Kodak Co.**

COLLIMATION OF LIGHT FROM A SOURCE OF FINITE EXTENSION.

For a point-source perfect collimation, with a perfect lens, is obtained by placing the source at the focus of the lens. If, however, the dimensions of the source are not negligible, the emergent rays are inclined to each other and to the optical axis, even if the (flat) source be placed in the focal plane. It then becomes of interest to inquire whether some other position of the light source gives a nearer approach and to actually find the position giving the nearest approach to perfect collimation. This is the object of the paper.

As a numerical measure (D) of the deviation from perfect collimation is defined the mean value of the angle of inclination of the emergent rays to the axis of the optical system, this mean being obtained by averaging first over the rays issuing from a fixed point of the source and then over the whole area of the source or, equivalently, over that of its image. A formula for the deviation D thus defined is constructed for the case of a disc-shaped source and is discussed in general terms and on a numerical example illustrating the dependence of D upon the distance and the size of the source and

* These abstracts have not been corrected by the authors.

upon the effective aperture of the lens. The position of nearest approach to perfect collimation, which turns out to be extra-focal, is determined and the corresponding minimum deviation D is compared numerically with that belonging to the focal and to some other positions of the source.

The present paper will appear in full in J.O.S.A. and R.S.I.

15 min.

(Received January 19, 1926)

2. Dr. Clayton H. Sharp — **Electrical Testing Laboratories**

Various Applications of the Photoelectric Cell with Amplifier to Photometry.

A.—An arrangement whereby a photoelectric cell with a vacuum tube amplifier supplants the ordinary photometer head in making a photometric balance has been described before the Illuminating Engineering Society in September 1925. A rotating glass disc, one half of which is silvered, throws in alternation the light of the "X" lamp and the light of the comparison lamp on to the photoelectric cell, the cathode surface of which is connected to the grid of an amplifying tube. If the two lamps differ in their effect on the cell, variations in the plate current are produced which act through a transformer and through a rectifying device upon a DC galvanometer. Equality is indicated by zero deflection. Experience has shown that unusual accuracy and speed can be obtained in photometric work with this device.

B.—Spectrophotometry.

The filament of an incandescent lamp is focussed on a spectrometer slit, the beam passing through a variable sector. The photoelectric cell with amplifier is the detector. A circuit connection is used such that the galvanometer shows only the changes in the plate current. Spectrophotometric measurements of transmission are made by noting the deflection of the galvanometer when the filter is interposed in the beam, and then by means of the sector bringing the galvanometer to the same deflection when the filter has been removed.

C.—Temperature of Lamps.

The ratio of light transmitted by a blue filter to that transmitted by an amber filter as shown by the photoelectric cell varies with the temperature of the source of light. The temperature of incandescent bodies can thereby be determined, using a calibration curve.

In using the photoelectric cell with an amplifier, especially when the amplifier has no grid leak, very thorough electrostatic shielding is essential. Low frequency magnetic disturbances are the most difficult to eliminate.

10 min.

(Received January 21, 1926)

3. L. A. Jones and V. C. Hall — **Research Laboratory, Eastman Kodak Co**

On the Relation Between Time and Exposure in Photographic Exposure.

Further results of the study of the reciprocity relation between the time of exposure and the intensity of exposing radiation are given. It has been found that the maximum density obtainable with complete development is dependent upon the intensity used. in making the exposure. This indicates that for the silver halide grains there is an intensity threshold below which developability can not be produced no matte how ong the exposure time is prolonged. It has also been found that if the exposirng intensity be sufficiently high all of the silver halide present in the emulsion is made developable.

The present paper will appear in full in J.O.S.A. and R.S.I.

20 min.

(Received January 20, 1926)

4. Harley E. Howe **Cornell University**

THE COLOR TEMPERATURE OF THE GAS-FILLED TUNGSTEN LAMP AS A FUNCTION OF TIME IN SERVICE.

Certain gas-filled lamps, used as secondary standards of color temperature, were found to require an increase in voltage and current as they aged in order to maintain them at 2848°K. To test for uniformity of behavior, groups of lamps of four different types were put on a life test at voltages that initially brought the lamps in each group to 2848°K. At intervals the color temperature of the lamps was measured with the rotatory dispersion colorimeter at the Bureau of Standards.

Each lamp showed erratic variations from a mean temperature, the average range covered being about 60°. For a lamp not under life test, a large number of observations distributed in time gave temperatures covering a range of 30°. The lamps tested at 2848°K showed no indication of a definite aging effect.

Three 9 volt headlight lamps, burned at the voltage necessary to bring them initially to 3000°K, showed drops of 100° during their life of 40 hours.

The effect of preliminary "seasoning," such as is carried out with photometric standards, was less than the observational error in temperature measurements.

The author concludes that in color temperature measurements frequent checks against primary standards should be made. For rough work only, constancy of color temperature at a constant voltage may be assumed.

10 min.

(Received January 21, 1926)

5. K. S. Gibson **Bureau of Standards**

THE PRODUCTION OF RADIANT ENERGY OF UNIFORM INTENSITY OVER THE VISIBLE SPECTRUM.

It has been found desirable in certain colorimetric work at the Bureau of Standards to have a filter which would reduce the relative energy of the Abbot-Priest artificial average noon sunlight to a constant energy value throughout the visible spectrum. The attempt was made to reproduce the ideal filter for this purpose as closely as possible spectrally, with the unavoidable variations of such a nature that the dominant wavelengths and purities of the actual and ideal filters should agree within the respective limens.

Considerations of permanence and convenience in handling favored the use of colored glasses in preference to solutions or dyed gelatine films. A study of the available glasses resulted in a choice of the following two in combination:

1. Am. Opt. Co. Amethyst C, thickness 1.26 mm. (Cf. B. S. Tech. Pap. 119, Fig. 15, curve C.)
2. Ives-Brady Daylight Glass, thickness 0.30 mm.

The following data will be illustrated:

1. The relative spectral energy of Abbot-Priest artificial average noon sunlight.
2. The spectral transmission of the ideal filter required to reduce this sunlight to equal energy.
3. The spectral transmission of the actual filter (above specified) designed to duplicate the ideal filter.
4. The relative energy of Abbot-Priest sunlight after transmission by the actual filter.

The agreement in color between the actual and ideal filters may be noted from the following table:

Dominant Wave-Length and Purity of Filter, Referred to Average Noon Sunlight (Abbot-Priest) as Neutral Standard.

1. Computed on basis of O.S.A. "Excitations" and "Luminosity Coefficients" (from spectral transmission)	Dominant Wave-length	Purity
Ideal filter	569.0C	−0.22
Actual filter	568.2C	−0.21
2. Observed (actual filter)		
K. S. G.	568.6C	−0.18

Bibliography:
Priest: Phys. Rev., (2), *11*, p. 502. *Cf.* "Standard Artificial Sunlight": 10th Annual Meeting, O. S. A.

5 min.

(Received January 20, 1926)

6. Irwin G. Priest **Bureau of Standards and Munsell Research Laboratory**

AN EXPERIMENT BEARING ON THE ADOPTION OF A STANDARD NEUTRAL STIMULUS IN COLORIMETRY: THE CHOICE AS BETWEEN "SUN" AND "EQUAL ENERGY."

Twenty-five observers viewed a photometric field under the following conditions: (1) *Shape*: Square, divided vertically into two halves. (2) *Size*: Side of square subtends 4°. (3) *Brightness*: 2 to 4 millilamberts. (Two halves equal, and surrounding field dark.) (4) *Pupil*: Circle, 3 mm diam.

One-half was illuminated by standard artificial noon sunlight, the spectral distribution in the other half being a close approximation to equal energy for all wave-lengths in the visible.

The names assigned to the colors of the halves of the field were, in general, somewhat as follows:

Sun: Yellow, green or greenish yellow.

Equal Energy: Pink, purple or blue.

When either stimulus acts alone (with dark surrounding field), the color is readily admitted to be neutral in either case; but when in juxtaposition, *neither* appears neutral, one or two observers being excepted. In general, for most observers, both colors, even in juxtaposition, are very pale tints. One observer, on her own initiative, called the sunlit half "greenish yellow" and the other "white." Others had to be urged to choose which color was the closer approximation to white, i.e., when seen together in juxtaposition, which was the *less saturated*. With two or three exceptions, the observers were in complete ignorance of the nature of the experiment.

The vote for less saturation (or closer approximation to "white") stands as follows:

For equal energy without doubt	15
For sun without doubt	3
For equal energy, but doubtful	1
For sun, but doubtful	2
Unable to see difference	2
Able to see difference but unable to decide	2
Total	25

This result suggests that an "equal energy source" is worthy of serious consideration as a neutral standard; but, pending other experiments, we refrain from definitely recommending it.

Bibliography:
Priest: B.S. Sci. Pap. 417 or J.O.S.A. *5*, pp. 205–209, 1921.
Priest: "Standard Artificial Sunlight," 10th Annual Meeting, O.S.A.
Gibson: "Equal Energy Spectrum," this program.
Helmholtz: Physiol. Op. O.S.A. Eng. Trans. vol. 2, p. 274.

10 min

(Received January 20, 1926)

7. Irwin G. Priest and F. G. Brickwedde Bureau of Standards and Munsell Research Laboratory

THE MINIMUM PERCEPTIBLE COLORIMETRIC PURITY AS A FUNCTION OF DOMINANT WAVE-LENGTH WITH SUNLIGHT AS NEUTRAL STANDARD.

Method and Conditions: A 4° square, two-part, field, symmetrical about a vertical division and viewed through a pupil 3 mm in diameter, is illuminated in both parts by artificial sunlight, at a constant brightness of about 3 or 4 millilamberts, with a surrounding field of about 0.5 millilambert. Homogeneous light is added to one-half, and sunlight simultaneously subtracted so the field remains matched in *brightness*. We attempt to make two adjustments of the mixture: (1) The least purity perceptible with certainty, (p_{max}); (2) The greatest imperceptible purity, (p_{min}). Care being taken to correct for stray light, the purity of these mixtures is then measured, accuracy being obtained by measuring a *known large multiple* of the homogeneous brightness.

Results: (1) For shortest wave-lengths, the mean of p_{max} and p_{min} is very small (0.001 or less); (2) increases slowly to about 0.02 at 550 mμ; (3) rises rapidly to a sharp maximum at about 570 and falls still more rapidly to about 0.02 at 580; (4) there is then a gradual fall to less than 0.01 at 640 mμ beyond which we have no data. For Brickwedde the wave-length of the maximum (precisely determined) is 568 mμ, the values for p_{max} and p_{min} being respectively 0.062 and 0.024. The corresponding wave-length for Priest (less precisely determined) is probably greater but not more than 572 mμ.

Remarks: 1. Least perceptible purity is largely dependent upon visibility; the relative amounts of *energy* required to introduce a hue difference show comparatively small variation with wave-length.

2. The wave-length at which least perceptible purity with sunlight as neutral is a maximum approximates very closely to the dominant wave-length of sunlight referred to equal energy spectrum as neutral. On the basis of the O. S. A. Colorimetry Committee "excitations" the latter wave-length is 569.0 mμ.

3. Further extensive investigation of least perceptible purity should be prefaced by a definite adoption of a neutral standard.

Bibliography:
(1) Priest: J.O.S.A. & R.S.I., 8, pp. 173–200 (for definition of purity and description of apparatus).
(2) Priest: "Standard Artificial Sunlight," 10th Ann. Meeting, O.S.A.

15 min.

(Received January 20, 1926)

8. W. F. Meggers & C. C. Kiess Bureau of Standards

SPECTRAL STRUCTURES FOR ELEMENTS OF THE SECOND LONG PERIOD.

In 1924 a summary of the regularities found in arc and spark spectra of elements in the first long period (K-19 to Fe-26) was published[1] and the *displacement law* of spectroscopy was verified across the entire chemical table. During the past year similar results have been obtained for some elements of the second long period (Rb-37 to Pd-46), and the main features of these spectra are now presented because of their interest for the development of the theory of multiplet structures. The spectra dealt with are those of Rb, Sr, Y, Zr, Cb, Mo, ekaMn, Ru, Rh, and Pd, most of the details being for the four elements following Sr. Typical multiplets representing systems of various permanent multiplicities and involving the most important spectral terms are given for each spectrum. The *displacement* and *alternation* laws are again found to be strictly valid, but some important differences between the spectra of the elements in the second long period and those of analogous elements in the first long period are noted. In connection with the empirical data, it is pointed out that the rule governing interval ratios of complex spectral terms is more frequently violated in spectra of heavy elements and deviations from the Landé g factors defining the Zeeman patterns of the spectral lines are not uncommon. The most sensitive lines for the purpose of spectrographically

detecting a chemical element (*raies ultimes*) which were formerly believed always to involve the spectral term of lowest energy (normal state of the atom) appear in a few cases (Mo II?, Pd I) to originate with somewhat higher energized states when the corresponding terms are represented by considerably larger quantum numbers.

The normal states of the neutral atoms Rb to Pd are represented by the spectral terms

$$^2S,\ ^1S,\ ^2D,\ ^3F,\ ^6D,\ ^7S,\ ^6S?,\ ^5F,\ ^4F,\ ^1S,$$

and the normal states of the ionized atoms Sr to Mo by the terms

$$^2S,\ ^3D,\ ^4F,\ ^5F,\ ^6S?,$$

respectively.

Bibliography:

1. Meggers, Kiess and Walters, Jr., J.O.S.A. & R.S.I., 9, 355; 1924.

The present paper will appear in full in J.O.S.A. and R.S.I.

15 min.

(Received January 20, 1926)

9. Irwin G. Priest **Bureau of Standards and Munsell Research Laboratory**

BLUE SKY AND WHITE SNOW:

A Note on Sensation and Perception. (Illustrated by an Illusion Discovered by Prof. C. A. Skinner.)

This paper is the sequal to a paper, "Gray Skies and White Snow," (Physical Society, Optical Society, N. Y., February, 1925). A beautiful illusion, discovered by Skinner will be described and used as an introduction to the discussion of the perception of saturation. In the previous paper it was shown that the brightness of an area of overcast sky perceived as "gray" might be greater than that of an area of snow perceived as "white," and that the "value" of a perceived color depended upon the observer's opinion as to whether the area in question was sky or snow. In this paper it is shown that similar relations exist in regard to saturation.

On a clear sunlit day with blue sky, cast shadows on the snow are blue. Physicists and other clear thinkers must admit that this is true ("objectively"); artists and other keen observers see it so. However, it appears that the highest degree of saturation of the blue shadows is not experienced while the observer is fully conscious of the snow. Let this consciousness be eliminated (or merely reduced in intensity) and the saturation increases in a most marked degree. Distant snow banks assume the illusory character of "equivocal figures," being perceived in alternate moments now as white snow banks in shadow and now as *blue lakes*, without any change in objective conditions (Skinner's illusion).

In the image on a camera ground glass, the shadows on snow are much more saturated than in a direct view of the landscape.

It seems certain that no physical hypothesis as to conditions external to the observer can account for these "illusions," It does not seem likely that they can be explained by retinal conditions. They are rather in accord with Helmholtz's ideas of perception.

The fundamental principles involved in this and the previous paper are not new; but they have not received the general recognition which they merit. They have a direct and important bearing on the problems of colorimetric standards and nomenclature, indicating that the nomenclature and standards of colors in *perception* is a much more complex subject than in mere sensation and deserves in itself more careful consideration than it has been accorded.

Bibliography:

1. Priest: J.O.S.A. & R.S.I., *11*, p. 133; August, 1925.
2. A. H. Munsell: "A Color Notation" or Century Dictionary (for definition of "value").
3. "Report of Colorimetry Committee" J.O.S.A. & R.S.I., *6*, p. 527.
4. Helmholtz: Physiol. Op. O.S.A. Eng. Trans. Vol. 2, pp. 131, 272, 297, (footnote 17), and 300; and Vol. 3, p. 286.
5. Luckiesh: "Visual Illusions" (N. Y. 1922), Chap. V.
6. Troland: "Mystery of Mind" (1926), pp. 88–96.

10 min.

(Received January 20, 1926)

FRIDAY MORNING AT 10 O'CLOCK

Session of the Physical Society

1. The Hall effect in sodium and potassium. E. S. BIELER, McGill University.—It is not generally recognized that there is one group of metals for which the Hall effect is strictly normal, as far as present measurements indicate, namely the metals of Group I of the periodic table. Data for Cu, Ag, and Au are fairly numerous and concordant; those for the alkali metals are scanty. Tests have been carried out on samples of Na and K filtered in a vacuum when in the molten state, and cast in glass cells of suitable shape. The results indicate that the Hall effect is what would be expected if these metals have one conducting electron per atom. The experiments are being carried on with Li, and will be continued with Rb and Cs.

2. Crystal size and hysteresis in precipitated magnetite. LARS A. WELO and OSKAR BAUDISCH. The Rockefeller Institute for Medical Research.—Magnetite has been prepared by three methods previously described (*J. Biol. Chem.* **65,** 216, (1925)). These oxides will be referred to as Lefort's, Haber's, and B and W's. In the present study the usual method of preparation of the latter oxide was departed from by boiling in excess of alkali. The oxides are of identical crystal structure but the average crystals differ in size. This is known from the relative sharpness and diffuseness of the diffraction lines. Lefort's oxide has a small average crystal, Haber's an intermediate size, and B and W's the largest crystals. Their magnetic properties have been studied. Barring the unknown but possible influence of impurities (sulphates to the extent of about 2 per cent) unavoidably occluded at the moment of precipitation, the conclusion is that lean hysteresis loops, low coercivities and low remanences are associated with oxides composed of small crystals. The significant constants for Lefort's, Haber's, and B and W's oxides are respectively: permeability maximum at 50, 240 and 380 gausses; coercivity of 14, 67 and 149 gausses; remanence of 8, 18 and 34 per cent. The relative areas of the hysteresis loops are as 1, 5 and 7.

3. Heat transfer in the annular space between two coaxial cylinders. S. R. PARSONS, University of Arkansas.—Two brass tubes are mounted with a common axis, one inside of the other, and are warmed by driving hot air, in turbulent flow, through the annular space between them. The rates of transfer of heat to the two tubes are compared by means of a coefficient representing heat transmitted per unit time per unit area of metal surface per unit difference of temperature between metal and air. Lees has shown that in streamline flow there would be a difference in the surface friction per unit area for the two tubes, and if that were true of turbulent flow, there should be a corresponding difference in the coefficients of heat transfer. Experiments show that if there is such a difference, it is not of the magnitude that would be expected from Lees' equations, and fail to show with certainty that any difference exists.

4. Thermal expansion of tungsten. PETER HIDNERT and W. T. SWEENEY, Bureau of Standards.—This paper gives the results of an investigation on the linear thermal expansion of tungsten (99.98 per cent) over various temperature ranges between −100 and +500°C. The expansion of tungsten is given by the following empirical equation: $L_t = L_0[1+(4.28t+0.00058t^2)10^{-6}]$, where L_t represents the length of the metal at any temperature t between −105 and +502°C, and L_0 the length at 0°C. Average coefficients of expansion for various temperature ranges are given in the following table.

Average Coefficients of Expansion per Degree Centigrade.

−100 to −50°C	4.2×10^{-6}	−100 to 0°C	4.2×10^{-6}
− 50 to 0	4.3;	0 to 100	4.3;
0 to +50	4.3;	0 to 200	4.4;
+ 50 to 100	4.4;	0 to 300	4.5;
100 to 200	4.5;	0 to 400	4.5;
200 to 300	4.6;	0 to 500	4.6;
300 to 400	4.7;	−100 to 500	4.5.
400 to 500	4.8;		

5. The production and measurement of a beam of neutral molecules. THOMAS H. JOHNSON, Yale University.—A beam of mercury vapor was formed by a condensation method similar to that used by R. W. Wood. A movable ionization gauge of the Buckley type, provided with a narrow slit, was used to explore the region traversed by the beam. A beam having a diameter of 0.5 mm at a distance of 8 cms from the last collimating aperture was produced and vacuum conditions were obtained whereby the pressure in the ionization gauge could be nearly tripled by moving the slit into the beam. The half-value period for pressure changes was of the order of a few seconds of arc. The method has been developed for use in measuring magnetic moments.

6. Cavitation in the track of an ultrasonic beam. R. W. BOYLE and G. B. TAYLOR' University of Alberta.—In a short paper in 1922 the first of the authors pointed out the possibility of the amount of sound wave energy transmissible through a fluid being limited by a phenomenon of cavitation, the evidence of which would be the formation of bubbles in the track of the waves. This phenomenon has been observed experimentally in the case of ultrasonic waves, where the energy is concentrated in the form of a narrow angle beam. Considering hydrostatic pressure (p_0) only as a preventive of disruption in the medium, the maximum energy transmissible across a square centimeter would be $p_0^2/2\rho c$, ρ being the density of the medium and c the velocity of the waves in it. But experiments, in a preliminary study of this phenomenon, have shown that this type of cavitation is more readily produced in highly volatile liquids; in which case, taking vapor pressure (p_v) into account, the maximum energy transmissible per sq. cm. would be $(p_0-p_v)^2/2\rho c$. The preliminary experiments show that cavitation occurs at much lower energies still, the energies being measured by the method of the torsion pendulum. It is evident that this phenomenon can limit the amount of energy transmissible in sound waves.

7. Measurements of street noise in New York City. E. E. FREE, 175 Fifth Ave.' New York City.—A systematic survey has been made of the street noise of New York City, using the 3-A audiometer devised by the Bell Telephone Laboratories, Inc. A standard buzzer note produced by this instrument is allowed to enter the ear of the observer, simultaneously with the street noise. The intensity of the buzzer note is adjusted until it just masks the street noise. Street noise was found to be due practically entirely to traffic, the automobile truck being by far the greatest noise producer, with street cars and the Elevated Railway making much smaller contributions to the noise level. The physical intensity of the street noise, estimated by calibrating the ear of the observer, was found to vary between approximately .001 dyne per square centimeter and approximately 20 dynes per square centimeter.

8. A precision determination of the electrical conductivity of concentrated aqueous solutions of calcium chloride. MARGUERITE CROW, McGill University. (Introduced by A. Norman Shaw).—Measurements are reported which give the electrical conductivity of solutions of calcium chloride for concentrations of from 25 percent to 50 percent and for temperatures from 10°C to 30°C with a precision of 5 parts in 10,000, which is greater than that of the values given in existing tables for these concentrations. Redeterminations of temperature coefficients are also given. Descriptions of the method and of the special precautions required in this type of precision measurement are outlined. The applications of these measurements in connection with electrical hygrometry are also described.

9. The redetermination of the temperature coefficients and the ageing corrections for new and old standard cells of the normal and the acid types. H. E. REILLEY and A. NORMAN SHAW, McGill University.—A brief report is presented, dealing with (a) a comparison of the temperature coefficients of various types of standard Weston Cells, and (b) the redetermination of the "ageing correction." The temperature coefficient investigation has been undertaken in order to examine the alleged eccentric variations

in the case of old Weston cells of all types, and particularly acid cells, new or old. Results have been obtained which only partly confirm the data reported by other investigators. The "ageing corrections" used by the writers for some years have made it possible to determine the "international mean" for the e.m.f. of a normal standard cell from old cells with a degree of accuracy equal to that obtained by using large numbers of new cells. This has been checked by ten formal exchanges of cells with the Bureau of Standards and the National Physical Laboratory (Teddington) over a period of seventeen years. This report gives results of apparently higher precision than have been recorded heretofore.

10. Small Einthoven galvanometer. HORATIO B. WILLIAMS, Columbia University.—Theoretical work undertaken for another purpose pointed to the possibility of designing a very small string galvanometer. Criticism of the theory and comparison of its consequences with experimental data having shown its probable soundness, the instrument was designed and built. Its performance corresponds with predetermination. It weighs 5.2 kg which may be compared with 100 kg, the weight of the original instrument, and 18 kg, the weight of the smallest accurate and sensitive string galvanometer hitherto available. The stray field has been much reduced, and at a short distance from the instrument is of the same order as that from an ordinary ammeter with permanent magnets at the same distance. The powerful optical system of the larger instruments is retained. Strings are mounted in interchangeable carriers. The instrument is robust and portable and at ordinary sensitivities very little affected by mechanical vibration. A sensitivity of 5×10^{-10} ampere/cm has been easily attained and is probably not the limit of its performance.

11. Radiation arising from the formation of helium from hydrogen. G. E. M. JAUNCEY and A. L. HUGHES, Washington University.—The loss of mass when four protons and two electrons come together to form a helium nucleus signifies a loss of energy which appears as a quantum. Conservation of energy and of momentum must both be satisfied. Four processes are considered: (1) the protons and electrons initially at rest produce a helium nucleus recoiling in the opposite direction of the quantum, (2) the protons and electrons all initially having velocity βc produce a helium nucleus at rest, (3) one proton with velocity βc meeting three protons and two electrons at rest produces a helium nucleus at rest, (4) one electron with velocity βc meeting four protons and one electron at rest produces a helium nucleus at rest. Solving for λ and β we find: $\lambda = .0004$A in (1), (2), (3) and .0008A in (4); $\beta = .008$ in (1), (2), .03 in (3) and .9995 in (4). The reverse of (4) is the photo-electric effect. By analogy with x-rays, .0004A and .0008A may be considered as critical absorption wave-lengths. This suggests looking for a trace of hydrogen in a tube of helium after the tube has been exposed to Millikan rays.

12. Radiation from the mutual annihilation of protons and electrons. A. L. HUGHES and G. E. M. JAUNCEY, Washington University.—Mutual annihilation of a proton and an electron on collision giving a quantum of radiation of wave-length 1.3×10^{-5} A has been suggested as the source of the high frequency radiation discovered by Millikan. It can be shown that this simple process cannot simultaneously conserve energy and momentum. Moreover it is difficult to imagine the reverse process, which would require a quantum suddenly, without apparent cause, to disappear, leaving in its place a proton and an electron. Both energy and momentum can be conserved in a *three body* collision. *Two electrons and one proton* colliding result in a recoil electron moving with a minimum velocity $.9999995c$, and a quantum whose wave-length is 2.6×10^{-5}A (or less). *Two protons and one electron* colliding result in a recoil proton moving with a minimum velocity $.6c$, and a quantum whose wave-length is 1.9×10^{-5}A (or less). The reverse process is as easy to realize as the forward process. An electron (or a proton) colliding with a quantum (having sufficient energy) causes the quantum to disappear leaving two electrons and one proton (or two protons and one electron).

13. Diffraction by a grating. G. BREIT, Carnegie Institution of Washington.—Frauenhofer diffraction phenomena have been explained by Duane in terms of transfer of momentum to the diffracting apparatus. It has been shown by Ehrenfest and Epstein using Compton's modification of Duane's theory, as well as by the writer on a different basis, that Duane's explanation may be made quantitative. In the present paper the requirement of proper maintenance of equilibrium in black body radiation is applied. It is shown that Duane's grating does not acquire the proper kinetic energy when exposed to black body radiation if quanta are conceived of as mechanical entities. On the contrary it is necessary to introduce probabilities of interaction similar to those used by Einstein in his 1917 needle quanta paper. In such a way the scattering by a grating is similar to the scattering by free electrons (Pauli) and by Bohr atoms. The conditions for interference come out, therefore, simply as selection rules. This point of view explains also Fresnel diffraction phenomena. This continuous transition from a Bohr atom *via* Hertzian oscillator to a grating is traced.

FRIDAY AFTERNOON AT 2 O'CLOCK

Session of the Physical Society

The presentation of papers will be suspended at 3 o'clock when a lecture will be given, at the invitation of the Optical Society, by PROFESSOR FRANK ALLEN of the University of Manitoba on

The Second Half of Vision.

14. Reflection of soft x-rays. ELIZABETH R. LAIRD, Mount Holyoke College.—This work continues some done in 1922 with a thermoluminescent detector. Electrons from a low temperature cathode fall on a target, the x-radiation produced passes through a tubular slit into a reflector which can be set at different angles or pulled aside. The reflected or incident beam falls on a Schumann plate. For copper at 1000 volts the result indicates total reflection at a glancing angle of about 5°, and very little for larger angles. At 500 volts the transition is less marked. For this voltage strong reflection occurs at 25°, for 265 volts at 35°, and for 160 volts at 8°. For larger angles the reflection at 160 volts is not as strong as at 265 volts, suggesting the passing of a natural frequency. Nickel at 500 and 1000 volts is similar to copper. Aluminum at 265 volts shows little reflection. Computation of critical angles by the Drude-Lorenz formula depends on values ascribed to natural frequencies, and to wave-lengths of maximum energy for a given voltage. Values for copper of 4° and 14° were computed for 1000 and 500 volts. The experiments show that these Schumann plates become less sentisive for equal energy as wave-length diminishes. The experiments will be continued looking towards more precision in measurement. This work was done at the Sloane Laboratory, Yale University.

15. The fine structure of the K x-ray absorption edge of calcium. GEO. A. LINDSAY and GEO. D. VAN DYKE, University of Michigan.—The absorption spectrum of calcium was photographed by the use of a Siegbahn vacuum spectrometer. The absorption occurred in the calcite crystal, thus rendering a screen unnecessary. A gypsum crystal was also used. The edge obtained from the calcite crystal showed two white lines and a wider absorption region farther towards shorter wave-lengths. The gypsum showed one strong narrow white line with faint traces of a second, while the third wider absorption region was about like that from the calcite crystal. The difference between the first and the second white lines was about 13 volts, between the first edge and the beginning of the third, about 30 volts. If the calcium is in the form of an ion in the compound, the K electron which is removed by the absorption is more likely to stop in one of the orbits normally occupied by the valence electrons, or in an orbit somewhat farther out than it would be if the atom were neutral, for the ion has a net charge of +2. This may explain the appearance of the white lines. These multiple edges seem to be found oftener for compounds (which are probably ionized) than for elements.

16. Investigation of x-ray spectra by the method of visibility. LACHLAN GILCHRIST, University of Toronto.—Formulæ are derived which represent the distribution of intensity and the visibility in x-ray spectra when the analysing crystal is composed of a large number of parallel reflecting planes. In the development the primary sets of multiple reflections are taken into account and the source is not supposed to be strictly monochromatic, but to have a "width." For a perfect crystal the expression for intensity is $I=[b^2(1-b^2A^6B^4)^2/(1-A^4B^4)][P+2A^2B^2C_1\cos 4\pi Dm+2A^4B^4C_2\cos 8\pi Dm+\cdots\cdots]$ and the expression for visibility is $V=A^2B^2C_1/P$, where b and a are the coefficients of reflection and absorption, respectively. $A=1-a$ and $B=1-b$. P_1C_1, C_2, etc., $2D$, and m have the significance given to them by Michelson and Rayleigh in articles on interference phenomena. This agrees with the visibility in the spectra obtained with Calcite crystals by Bergen Davis and Stempel. For crystals with random or "irregular" spacing maximum and minimum intensities are given by $I=[b^2\Sigma_s^p A^{4p}B^{4p}/(1-b^4A^4)][P\pm 2b^2A^2C_1]$ and the visibility is given by $V=2b^2A^2C_1/P$. If the intensity at the minimum is zero when perfect crystals are used, which seems to be in accord with experimental results, then in spectra which are obtained by means of imperfect crystals the intensity at the minimum is not always negligible and deductions should not be made from the intensity of the maximum alone.

17. The scattering of x-rays. J. A. GRAY, Queen's University.—The x-rays scattered from different thicknesses of material have been examined by an absorption method. The thinner the material, the greater is the average wave-length of the issuing radiation. The results indicate that the modified "band" in scattered x-rays has a greater total intensity than is commonly supposed. From these and other results, it seems possible to explain the small intensity of reflection of x-rays from crystals for the larger angles of scattering. No evidence for the J phenomena has been found.

18. Electron distribution in sodium chloride. ARTHUR H. COMPTON, University of Chicago.—Extending Duane's method of Fourier analysis, a series expression is obtained for the mean electron density at different distances from the centers of the atoms in a crystal. Every term in the series may be determined by measurements of the intensities of the reflection of x-rays from the crystal, whereas in Duane's method a constant term remains undetermined. Using the data of Bragg, James and Bosanquet for the reflection from rock-salt, the electron density is found to fall definitely to zero for the sodium ion 1.1A, and for chlorine at 2.0A. from the center. Sodium has a group of eight electrons (probably K and $L2_2$) near the center with two electrons (probably $L2_1$) at .9A from the center. Near the center of the chlorine ion are 10 electrons (K and L) outside of which are eight others, resolvable into $4(3_3?)$ at .74A, $2(3_2?)$ at 1.14A and $2(3_1?)$ at 1.60A. These distances are uncorrected for thermal agitation. The electron distribution curves are similar to but show more detail than those obtained by Bragg and Havighurst from the same data.

19. Stark Patterns. J. STUART FOSTER, H. B. HACHEY and W. ROWLES, McGill University.—The simplest Stark pattern consisting of one parallel component and no perpendicular component (1/0) is observed for three members of the orthohelium series $2s-ms$. This pattern, together with others previously reported by one of the writers (Nature **116,** 135 (1925)) completes a group of Stark patterns 1/0, 1/1, 2/2, 2/3 which theoretically exist in the Balmer series. The parhelium combination line $2P-6P$, next the diffuse line in the 4144 group, is clearly observed as a separate line in lowest field. The dispersion 3A/mm makes the separation (0.26A) of these lines more definite than in a previous experiment (Phys. Rev. **23,** 667, 1924). The orthohelium lines near and including 4026 are observed as doublets in high electric fields. The observed separation is constant throughout.

20. A method for exciting spectra of certain metals. JOHN K. ROBERTSON, Queen's University.—An examination of the spectrum of tin when excited by the electrodeless discharge has shown that characteristic metal lines are brought out in the case of a discharge in a quartz tube containing residual gas and pieces of cold metal to about the same extent as when the tube was heated to 1000°C. To study the origin of the metallic lines, other metals were examined, in all cases sufficient hydrogen being left in the quartz tubes to carry the discharge. With silver and gold negative results were obtained, but with zinc and cadmium lines were present as in tin. Moreover, with these two metals, only ultimate and penultimate lines of the neutral or the ionized atom appeared. In cadmium, for example, the quartz spectrograph showed with marked intensity only $2144(1\sigma-1\pi_1)$, $2265(1\sigma-1\pi_2)$, $2288(1S-1P)$, $3261(1S-1p_2)$. Evidence is given that the explanation of the effect is found, not in the presence of vapor due to temperature, but as a result of some kind of reaction between active gas atoms and the metal or an oxide of the metal. The appearance of ultimate ionized lines and the non-appearance of higher members of neutral series is, however, somewhat puzzling.

21. Spectrum of copper. A. G. SHENSTONE, Princeton University.—In addition to a normal doublet spectrum, the copper arc yields a complicated spectrum built on the low inverted ^2D term which connects the two spectra. The Heisenberg-Hund theory predicts low terms ^4P, ^4D, ^4F, ^2P, ^2D, ^2F which should combine with the ^2D. Zeeman effects obtained on a Hilger E.1 spectrograph identify the term $\nu=22194.0$ as $^4P_2$ and $\nu=21364.3$ as $^4P_1$. The latter has a g equal to $2.5\pm.1$, (theoretical value $=8/3$). The two terms $\nu=17392.3$ and $\nu=16487.2$ have irregular g values equal to $.21\pm.01$ and $.51\pm.02$. They may be $^4D_1$ and $^2P_1$. The term $\nu=17763.9$ has $g=1.1\pm.1$ which must also be irregular. All the evidence indicates that this portion of the Cu spectrum has the characteristics of a spectrum of the second rank. In all 20 positive terms combining with ^2D have been found. These in turn combine with 21 negative terms and account for 175 arc lines including all the important ultra-violet and most of the important visible lines. Some constant frequency differences have been found connecting the prominent ultra-violet Cu^+ lines. Several lines have been identified from Zeeman patterns.

22. Critical potentials and the heat of dissociation of hydrogen as determined from its ultra-violet band spectrum. ENOS E. WITMER, National Research Fellow, Harvard University.—Lyman has found that under certain conditions of excitation the mixture of hydrogen with argon causes the former to emit a very simple, one-dimensional series of bands, lying between λλ 1063 and 1670. These bands are apparently Q branches with perturbations near the origin, and, as this investigation indicates, are excited as follows. The energy imparted to a hydrogen molecule is limited to 11.6 volts, the resonance potential of argon. This is just sufficient to raise the hydrogen molecule from the normal state, $e_t=1$, $n=0$ to $e_t=2$, $n=0$, where e_t is the total electronic quantum number, and n the vibrational. Returning, the jumps are $e_t'=2$, $n'=0$, to $e_t''=1$, $n''=0$ to 12. The curve $(n'', dE/an'')$ indicates that dE/an'' becomes zero shortly beyond $n''=12$, so that at $n''=12$ the molecule is on the verge of dissociation, and $n''=13$ apparently cannot exist. The data give the following molecular constants: lowest resonance potential = 11.61 volts; the heat of dissociation = 4.22 volts = 97,350 calories in agreement with Isnardi's (Zeit. Elektrochemie **21,** 405, 1915) value of 95,000 calories; the frequency of infinitesimal vibration ω_0 in the normal state = 4260 cm^{-1} in fair agreement with the value 4880 cm^{-1}, obtained by Kemble and Van Vleck (Phys. Rev. **21,** 653, 1923) from specific heat data. Combining this resonance potential with other spectroscopic data gives 15.2 volts as the probable ionization potential of H_2.

23. Interpretation of complex spectra. OTTO LAPORTE, Research Fellow, Bureau of Standards.—Recent development of the theory of atoms with several valence electrons, permits interpretation of the complex arc and spark spectra of the two long periods of elements. The low and metastable term group of the spectrum of an element with z

valence electrons and belonging to the second long period can be accounted for by the three configurations: $(z-2)$ electrons of type 4_3 and two 5_1, $(z-1)$ of 4_3 and one 5_1, z electrons of 4_3 and none of type 5_1. Hund has shown that the first and second kinds represent respectively the normal states of the neutral and simply ionized atoms from Ca to Ni. In the second long period, it is possible to show the presence of terms belonging to the third configuration in almost every spark spectrum. The tendency to eliminate the 5_1 electrons gradually becomes stronger towards the end of the period: Neutral Pd and the singly ionized atoms from Mo to Ag are normally in states with 4_3 electrons only. The new theory connects term differences in the spark with differences of series limits in the arc spectra. This is illustrated with Cr and Fe.

24. Standard wave-lengths for use in the extreme ultra-violet. STANLEY SMITH and R. J. LANG, (introduced by R. W. Boyle). University of Alberta.—Wave-lengths of a number of lines, chiefly of carbon, which frequently occur in the spectra of other elements, have been measured in the second and third orders on plates obtained in a vacuum spectrograph with a concave grating of radius 6 feet ruled with 30,000 lines to the inch. The dispersion was approximately 4.5A per mm. The carbon lines and the iron standard lines used as companions were obtained *simultaneously* by passing a condensed spark discharge between a carbon and an iron electrode. (1) *Method of measuring.* Details are given of a new method of obtaining the curves to correct (a) for deviation of the spectra from normality (b) for error in the tilt of the photographic plate. These curves can be used for correcting the calculated wave-lengths obtained by interpolation between any pair of standards chosen within the range of the curves. The curves for correction (b) is proved to be very approximately parabolic. (2) *Wave-length measurements* of the following lines have been made: 904, 977, 1010, 1036, 1175, 1215, 1247, 1323, 1329, 1335, 1548, 1550, 1561A.

SATURDAY MORNING AT 10 O'CLOCK
Session of the Physical Society

25. Approximating the "screening constant." D. T. WILBER, Cornell University.—A combination is proposed of the Sommerfeldt assignment of azimuthal quantum numbers of 1, 2, 3, 4, to the s, p, d, and f, terms, respectively and his value of the term energy, $R(Z-s)^2/n^2$ plus a negligible term, with a proposed approximation value for the "screening constant" s. This value takes the form $s=(1-k/4n)(Z-1)$ and $\nu=R[(1+(Z-1)k/4n)^2/n^2]$ is the energy value of a term of total quantum number n and azimuthal quantum number k. Calculating the value of the series terms of the alkalies from this formula gives a good check for the four series of lithium and follows the trend of the sharp terms up to caesium but shows a systematic and finally large deviation in the case of the p terms. In general this systematic deviation is proportional to the doublet separation. This formula does not compete with the Rydberg, Ritz or Hicks formulæ for accurate interpolation but does show how Bohr's values of total quantum number can be possible when so much larger than the usual value assigned the terms.

26. Cross-sectional area of an Einstein quantum. R. J. PIERSOL, Westinghouse Research Laboratory.—A gas kinetic treatment of the equilibrium of light quanta and electrons led Burger and Ornstein to the value $a\lambda^2$ for the cross section of a light quantum, where a is a universal, but unknown constant. By calculation from the vibration volume of the electron Marx showed $a=3/4\pi$, or that the area $A=3\lambda^2/4\pi$. It may be proved from the classical Hertzian theory of oscillators that, if the two electric doublets are parallel, the area of thermal absorption $A_t=3\lambda^2/4\pi$, which is identical with the result obtained by Marx from equilibrium considerations. But it is shown, in general, that where there are a large number of radiating and absorbing electrons, oriented at random, the area of electromagnetic absorption is $A_e=\lambda^2/\pi$. Therefore, the unknown constant in the equation of Burger and Ornstein is $a=1/\pi$ instead of $a=3/4\pi$. Numerically this value is very close to that obtained by Marx, and therefore either value satisfies the interference and diffraction of light.

27. The electro-magnetic equations of light propagation in molecular media of varying density. LOUIS V. KING, McGill University.—If (X, Y, Z) be the electric intensity in the incident light-wave at (x, y, z), it is customary to add to the displacement-current $(1/4\pi)\partial X/\partial t$ the convection current $ne\,dx/dt$ arising from the motions of the dispersion charge e at (x, y, z) having space-density n. The equation (1) $(u, v, w)=(1/4\pi)\partial(X, Y, Z)/\partial t+ne(\dot{x}, \dot{y}, \dot{z})$ for total current densities (u, v, w) at (x, y, z) is usually stated to follow from the *fundamental* Maxwell-Lorentz equations (2) $(u, v, w)=(1/4\pi)\partial(X, Y, Z)/\partial t+\rho(\dot{x}, \dot{y}, \dot{z})$ ρ being, however, the space-density of electricity supposed continuously (and uniformly) distributed. In fact, a closer examination requires us to replace (1) by three equations of the type (3) $u=(1/4\pi)\partial X/\partial t+ne\dot{x}+(1/4\pi)\int[(\xi-x)/r^3][\partial(ne\xi)/\partial\xi]dV$, where $r^2=(\xi-x)^2+(\eta-y)^2+(\zeta-z)^2$, the volume integral being taken to include all dispersion charges. It thus appears that (1) as derived from (2) is exact only for media of constant density and of unlimited extent. The additional term in (3) may be expected to give rise to second order phenomena such as *light scattering* arising from elastic density fluctuation due to thermal agitations.

28. Analysis of positive ions emitted by a new source. G. P. HARNWELL, Princeton University, and H. A. BARTON, Harvard University.—Certain iron oxide crystals containing about 1 per cent of some alkali metal or alkaline earth have been developed by the fixed Nitrogen Research Laboratory for use as catalysts in the synthesis of ammonia. It has been found that these substances have also great utility as constant and abundant thermionic emitters of positive ions (Kunsman, *Science*, **62**, 269 (1925)). The writers have analyzed their emission by the use of a mass spectrograph which has been described by Smyth. Separate catalyst samples containing respectively Na, K, Rb, Cs, Mg, Ca, and in one case both Ba and Sr have been shown in this way to emit only the corresponding singly charged positive ion. No doubly charged ions were observed, nor any ions of the other elements composing the catalysts. The alkali metal ions were emitted at lower temperatures than the alkaline earth ions. Particularly in the case of the latter, a preliminary treatment consisting of reduction at red heat in an atmosphere of hydrogen increased the emission.

29. Positive ray analysis of the ions in a discharge in hydrogen. H. D. SMYTH and C. J. BRASEFIELD, Princeton University.—Previous experiments by one of the authors and others indicate the importance of H_3^+ as a product of ionization in hydrogen. Considering the possible bearing of this result on the interpretation of the many lines spectrum the authors are now studying the relative concentrations of different types of ion in a striated discharge. The discharge is maintained between a filament and plate 20 cm apart in a tube of 5 cm diameter. In the side of the tube about half way between plate and filament is a third electrode, to which positive ions are drawn. Through a slit in this electrode some of the ions pass into a positive ray analysis apparatus of the type used before. Preliminary results give sharply defined "peaks" which are identified as due to H_3^+, H_2^+, and H^+. When the ions are drawn from the positive column, the H_3^+ ions are by far the most numerous though the H^+ peak is also strong. The H_2^+ peak is very weak increasing only slightly when the pressure is reduced from .2 mm to .03 mm. However at a pressure of .005 mm H_2^+ becomes slightly stronger than H_3^+. In the Faraday dark space H^+ apparently has the greatest concentration. Experiments are being continued.

30. Reconciliation of experiments on probability of ionization by electron impact. K. T. COMPTON and C. C. VAN VOORHIS, Princeton University.—Recent work in this field by Hughes and Klein, Jesse and the authors, shows considerable lack of agreement. It is shown that that of Hughes and Klein and of the authors is brought into fair agreement by correcting for three sources of error: (1) effect of the electric field on the effective area of holes in the grid through which primary electrons pass; (2) presence of slow secondary electrons and lack of homogeneity in velocities of primary electrons; (3) warming of gas by filament. These three corrections were determined for an apparatus

built like Hughes and Klein's. The second one only applies to our earlier results. As a result of such corrections our earlier values should be increased by about 10 per cent at electron velocities above 100 volts and somewhat more at lower velocities, and Hughes and Klein's results and ours are brought into approximate agreement. We could not reconcile Jesse's results with the others. Final corrected values of probability are given.

31. Photo-ionization of a gas by a discharge in the same gas. F. L. MOHLER, Bureau of Standards.—Measurements were made in a tube containing two thermionic units electrically screened from each other; one serving to give a discharge at measured current and voltage, the other operated at a constant low voltage so that the electron emission was limited by space charge. Photo-ionization of the gas in the second unit was detected by the increased thermionic current, resulting from neutralization of the space charge. Relatively little photo-ionization is produced by the arc spectrum while a strong effect is produced when the discharge voltage is sufficient to produce higher stages of excitation. The method is therefore well adapted for measuring higher critical potentials. Some of the results obtained are as follows: Caesium; ionization of 6_2 shell 13.0 volts, double ionization 21.5, ionization of 6_1, 39.0—Potassium; double ionization 32, ionization of 3_1 shell 48—Argon; double ionization 34.8, ionization of 3_1 shell 39.6—Neon; double ionization 54.9. In each case the most pronounced increase in photo-ionization came at the double ionization point and spark excitation stages at slightly lower voltages were also found.

32. Ionization potential and radius of the atom. A. S. EVE, McGill University.—The ionization potential is roughly inversely proportional to the radius of the atom as already shown for Group I and II in the periodic table (Nature **107,** 552 (1921)). This relation holds well for the rare gases whether the kinetic theory or Bragg's x-ray radii are selected. Glockler (*Phil. Mag.*, **50,** 997 (1925)) has directed attention to this relation, which is investigated more closely in the present communication.

33. A method of high precision for the determination of critical potentials and the ionization potential of mercury vapor. ERNEST O. LAWRENCE, National Research Fellow, Yale University.—Electrons from a hot cathode are bent into circles by the magnetic field of 60 cm Helmholtz coils, a portion thereof passing through a series of slits on a circle of 5 cm radius. Using a positive ion sheath to neutralize space charge, currents of the order of 10^{-9} amp. for ten-volt electrons emerge from the final slit. Retarding potential measurements show that the electrons have a sharp upper limit to their velocities which is the condition necessary for sharp critical potential curve "breaks" and ultimate precision in critical potential measurements. Such a beam of electrons was passed into the effectively field free space of a Faraday cylinder containing mercury vapor and a suitable electrode arrangement for detecting the formation of positive ions. Observing the potential of the cylinder at which ionization is detectable and the potential requisite to prevent the entrance of electrons gave the value 10.4 volts as the ionization potential of mercury vapor with a possible error of about one-half of one per cent. The method is so precise that the errors no longer lay in corrections for the curve breaks but in the measuring instruments.

34. Flow of ions through a small orifice in a charged plate. L. TONKS, H. M. MOTT-SMITH, JR., and I. LANGMUIR, General Electric Co.—To separate the ionic and electronic parts of the electric current to an electrode immersed in an arc, A. F. Dittmer suggested allowing the carriers to pass through small holes in one electrode, B, and collecting them on a second close parallel electrode, C. The undesired carrier can be prevented from reaching C by the potential of either B or C. Practically B must be negative with respect to A, C positive with respect to B. We have calculated the electric field about a circular hole in a thin infinite charged plate, the transverse velocity acquired by a fast charged particle passing through the hole and the effective change in the area of the hole due to focusing action. These results enabled us to calculate

the volt-ampere characteristic of C when collecting electrons having a Maxwellian distribution, or ions having Maxwellian and quasi-Maxwellian velocity distributions. The usual semi-log plot of the electron characteristic yields a temperature which is slightly high, the ion characteristic is linear for small accelerating voltages and its semi-log plot for retarding voltages is curved. The determination of current densities and carrier temperatures from the characteristics and the errors involved have been worked out.

35. The passage of charged particles through helium. A. J. DEMPSTER, University of Chicago.—The penetration of protons with 300 to 900 volt velocity in helium, reported in a previous paper, has been found to hold for much slower rays. With 14 volt rays the charged bundle of rays was observed at a helium pressure that would give six collisions for the path completed. The average loss of velocity per collision for the majority of the rays of 900 volt speed in penetrating 15 to 25 helium atoms is less than half a volt per collision. Other ions are neutralized or dissociated in helium, and an approximate free path may be deduced from the rate at which they disappear as the pressure is increased. With hydrogen molecule ions the free path for dissociation of 900 volt rays is about 17 times the kinetic theory mean free path for helium atoms. With slower rays (340 volts) the free path is still larger, 2.5 times greater than for the faster rays. Singly charged helium atoms are rapidly neutralized. If we calculate the number of collisions assuming an ion diameter equal to the atomic diameter given by the kinetic theory of gases, the helium ion makes, on the average, only 2.8 collisions before neutralization.

36. The "reflection" of electrons from the molybdenum target of a Coolidge x-ray tube. W. R. HAM and MARSH W. WHITE, Pennsylvania State College.—The method previously described by the writers (*Phys. Rev.* **27**, 111, (1925)) was used. This consists essentially of accurately measuring the energy input into the tube and the heat energy received at the anode. An approximate measure of the ratio of the number of impinging electrons to those emitted from the anode is obtained by taking the ratio of $(W_i - W_a)$ to W_i, where W_i is the energy input and W_a is the heat energy received by the anode alone. In the present experiments the data have been extended, with improved technique, to include molybdenum. The tube used was a standard molybdenum-button water-cooled type. Several improvements in the experimental arrangements were made, namely: the temperatures of the water used in the flow calorimeter were read to 0.001 degree by Beckmann thermometers, the water supply was changed to an elevated constant temperature bath and arrangements were provided for keeping the room temperature constant. The curve showing the percentage of "reflected" electrons vs. voltage is similar to that for tungsten, rising from 20 to 1.3 kv to a pronounced maximum 22.5 at 4 kv and rapidly falling off to 3 at 15 kv, where it remains approximately constant up to 30 kv.

37. Report on the failure of the mercury to gold transmutation experiment. H. HORTON SHELDON and ROGER S. ESTEY, New York University.—During the past year we have repeated the mercury to gold transmutation experiments of Dr. Miethe of Berlin and we have not been able to produce the slightest trace of transmuted gold. Our runs were made in three lamps; one horizontal, one vertical, and one a copy of that used by Miethe. The first ran for 30 hours, the second for 50 hours, and the third for 172 hours. The mercury from each run was carefully analyzed and the analyses checked with blank tests of minute known amounts of gold. We found no transmuted gold whatever, although a quantity fifty times smaller than Miethe claims to have produced in 197 hours was detectable with certainty. It is claimed that transmutation is due to instability of the arc conditions. Our experiments seemed to show more instability than that reported by Miethe, thus refuting that suggestion. The suggested explanation of a change of the number of electrons in the nucleus changing mercury to gold seems good in theory, but incredible in fact, for the potential drop per mean free path of a mercury molecule is only about 0.1 volt in these arcs.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program, to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for at any session after the completion of the regular program for the session.

38. The relation between the thickness of a partition in a medium and its reflection of sound waves—by the ultrasonic method. R. W. BOYLE and J. F. LEHMANN, University of Alberta.—Experiments carried out by the authors a few years ago by the method of ultrasonic waves—which offer convenience in this type of work—throw light on the problem of the reflection of sound waves by serving to confirm fairly well the existing mathematical theory by Rayleigh. From this theory, which in one aspect is approximate only, it can be deduced that at perpendicular incidence there should be maximum reflection of sound energy when the thickness of the partition is one-quarter the length of the wave in its material, and there should be no reflection but perfect transmission (neglecting absorption) when the thickness is a half wave-length. In the use of a torsion pendulum to make energy measurements in ultrasonics, a means is offered to test these points experimentally. The results obtained also have an essential bearing on the design of torsion pendulums for use in absolute measurements; and incidentally from them can be deduced a method of measuring the modulus of elasticity and velocity of sound in a solid.

39. A method of measuring relative intensities of Stark-effect components. J. STUART FOSTER and M. LAURA CHALK, McGill University.—A modified Lo Surdo tube with rectangular cross-section near the cathode is employed. At a given distance from the cathode the light intensity is constant over the central portion of the discharge in the Crookes dark space. The tube is placed with its axis horizontal and with the longer side of the rectangle in a vertical position. Light from very near the cathode is analyzed and found to give straight lines of uniform intensity corresponding to the different Stark-effect components. Using this source and a double neutral wedge, photographs of the p and s components of Hβ are obtained from which the relative intensities can be measured. Final results will be published when a check has been made on the wedge calibration.